

IMPACT OF PALM KERNEL SHELL ASH (PKSA) ON THE STRENGTH AND WATER ABSORPTION PROPERTIES OF EARTH BLOCKS

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The availability of housing for under-developed and developing countries is one of the most important needs of low-income groups. Housing is a very expensive requirement to meet. However, since land and construction costs are mostly beyond the means of both the rural and urban poor. Due to the exorbitant cost of steel, cement and crushed stone aggregate, including energy and importation costs, the development and use of other locally available materials are now being emphasized. The purpose of this paper is to examine the strength and water absorption of Palm Kernel Shell Ash (PKSA) when partially replaced with cement in Compressed Stabilized Earth Blocks (CSEB). An extensive review of literature reveals that limited study has been done in this area, leaving a research gap to be filled, hence the purpose of this paper. The results revealed that the higher the PKSA content, the longer the water absorption and setting time. This paper concludes that PKSA, a material found to have high pozzolanic substance can not only be used as partial cement replacement in concrete but also feasible to replace cement partially and increase the compressive strength and durability of compressed stabilized earth blocks in earth construction.

Keywords: Compressive strength, palm kernel shell ash (PKSA), agro-wastes, earth construction, water absorption.

INTRODUCTION

It has become difficult for rural and urban people to afford as the cost of land and construction are very high (Houben and Guillaud, 1994). Many governments have brought up housing schemes

which help to facilitate housing ownership for low income groups. It is very essential to find out ways to reduce the construction cost, at least for low income housing. This can be done focusing on locally

available material for construction purpose with proper and appropriate technology. There are so many traditional construction materials that exist in Nigeria which have over the years proven to be suitable for a wide range of buildings. These materials have a great potential for increased use in the future and one of such material is the Compressed Stabilized Earth Block (CSEB). The main objective of this research is examining the strength and water absorption of Palm Kernel Shell Ash (PKSA) when partially replaced with cement in Compressed Stabilized Earth Blocks (CSEB), in a bid to create a building material that is cost effective yet meeting the required building products standards and codes.

Previous researches have highlighted the use of PKSA as partial replacement for cement in concrete blocks but none has been done on CSEB.

Also, other researchers have studied the use of two different pozzolans in stabilizing earth blocks while some others have tried experimenting with industrial wastes both for concrete blocks and cement stabilized earth blocks.

LITERATURE REVIEW

Soils are variable and complicated materials, whose properties may be changed to boost performance in building construction by the addition of varied stabilizers. Soil is also referred to as the loose material that results from the long-term transformation of the underlying parent rock by the simultaneous and evolutionary interaction of climatic factors and other physico-chemical and biological processes (Houben and Guillaud 1994). Existing literature on Compressed Earth Blocks appear to adequately cover fundamental theories of soil properties and behavior.

Compressed Stabilized Earth Block (CSEB) is an improved form of one of the oldest materials in the building industry, a modern descendent of the moulded earth block, more commonly known as the "adobe block". The idea of compacting earth to improve the quality and performance of molded earth blocks is, however, not a new concept and since its emergence, the technology with which Compressed Earth Block is produced and its application in building has continued to gain ground and to prove its technical and scientific value.

Soil stabilization can be described as a method of improving the engineering properties and characteristics of the soil thereby making it more

stable. According to Kenya standard specification for soil blocks, 1990, stabilization is done for the purpose of improving the natural durability and strength of a soil by the addition of other materials.

The term stabilization is generally restricted to processes which alter the soil material itself for improvement of its properties. A connecting material or a chemical is added to a natural soil for the purpose of stabilization. The most commonly used technique for soil stabilization is Chemical Stabilization. The cementation method of the earth block leads to the embedding of soil particles among the matrix of cementitious gel, in other words, this acts as a coating layer round the soil particles.

Palm Kernel Shells (PKS) are derived from threshing or crushing palm fruit in the mill or factory to remove the palm seed after the palm kernel oil has been extracted (Olutoge, 2010). Palm kernel shells are available in large quantities in palm oil producing areas in Nigeria such as Okitipupa, Ode-aye farm settlement, Araromiobu rubber and oil plantations, Irele oil plantations in Ondo State, NIFOR and Okomu farms in Edo State and in reasonable quantities in other towns and villages especially in the southern part of Nigeria (Owolabi, 2012). PKSA has been found to have high pozzolanic substance making it suitable for use as partial cement replacement and also increase the compressive strength and durability of Compressed Stabilized Earth Blocks.

MATERIALS AND METHODS

MATERIALS

In the present study locally available loam soil, sand, ordinary Portland cement and PKSA were used for preparation of CSEBs. Loamy soils are an interposition between sand and clay. This soil generally encompasses a mixture of organic material, sand and clay. Loamy soils are appraised in the building industry to be adequate for building on, which means that they are superior to clay however worse than sand. It was ensured that the selected soil was air dried, pulverized to break the clods and sieved through 45 mm sieve. Ordinary Portland cement was used in the study conformed to requirements of Bureau of Indian Standard (IS: 8112). The selected soil was characterized for its physical properties namely, liquid limit, plastic limit, shrinkage limit, particle size distribution, and specific

Table 1. Properties of materials.

Soil Type	Specific Gravity	Liquid Limit	Plastic Limit	Shrinkage Limit	Plasticity Index	FSR	Max. dry density (g/cm ³)	Optimum moisture content (%)
Loam Soil	2.65	48.1	25.5	14.2	22.6	1.0	1.83	12
Sand	2.62	-	-	-	-	-	-	-

Table 2. Grain Size Distribution.

Soil Type	Gravel (%)	Sand (%)	Silt (size) (%)	Clay (size) (%)
Loam Soil	0	40	30	30
Sand	2	96	2	0

Table 3. Chemical Properties of Cement and Palm Kernel Shell Ash.

Chemical Composition (%)	OPC	PKSA
SiO ₂	20.78	59.15
Al ₂ O ₃	3.62	11.72
Fe ₂ O ₃	2.91	0.44
CaO	65.12	7.96
MgO	2.63	5.03
K ₂ O	0.48	4.76
True Density (g/cm ³)	3.15	2.73
Specific Gravity	3.17	2.47

gravity using the standard procedures as specified by Bureau of Indian Standards and the results are summarized in [Tables 1](#) and [2](#). Free Swell Ratio has been used as a simple method of identifying the presence of principal clay mineral in the soil (Prakash and Sridharan, 2004). The same has been reported in [Table 1](#). Free Swell Ratio (FSR) is defined as the ratio of equilibrium sediment volume of 10 g oven dried soil passing a 425 μ m sieve in distilled water to that in carbon tetra chloride. Sand was tested for its specific gravity and particle size distribution and the results are reported in [Tables 1](#) and [2](#) respectively. The standard compaction test for the soil was done in Standard Proctor mould and the optimum values are reported in [Table 1](#).

The chemical properties of both the Ordinary Portland Cement (OPC) and the Palm Kernel Shell Ash (PKSA) were tested and the results are shown in

Table 3.

The PKSA collected is brownish in color and the main constituents of the PKSA are Silicon (SiO₂), Aluminum (Al₂O₃), and Iron Oxide (Fe₂O₃). The total amount of SiO₂, Al₂O₃ and Fe₂O₃ present in PKSA is 71.31% which is more than the minimum required (50% Min.) specified by ASTM design standards, while its Calcium oxide (CaO) content is about 7.96%; as shown in [Table 3](#). The specific gravity of the PKSA was gotten to be 2.30; which was less than that of the OPC of 3.15. This indicates that a substantial higher volume of materials of high cementitious value will result from mass replacement for cement.

PROPORTIONING OF SOIL-ADMIXTURE MIX

Based on the extensive works carried out by various

Table 4. Proportions of constituents present in natural modified soil used.

Constituent	Natural Soil	Modified Soil
Sand	40	72.4
Silt	30	12.8
Clay	30	14.8

Table 5. Proportions of stabilizers used in the preparation of different series of Compressed Stabilized Earth Blocks (CSEBs).

Series	Modified soil (%)	Cement (%)	PKSA (%)
S1	90	10	0
S2	90	8	2
S3	90	6	4
S4	90	4	6

researchers, it has been shown that proper grading increases the density of the blocks, which in turn improves their compressive strength (Spence 1975). As a tenet, the simplest potential combination of ingredients would be 70% of sand and gravel, and 10% to 20% clay which results to great wet compressive strength of blocks (Houben and Guillaud, 1994; Olivier and Mesbah, 1987; Venkatarama and Jagadish, 1995). In this present study, soil used is loam soil, which has non-expansive clay mineral as inferred from FSR value being 1. The sand content of the reconstituted soil was maintained around 70% and clay content less than 15% (Table 4).

It has been reported in the literature that the optimum content of cement to get wet compressive strength of 3–5 MPa for compressed stabilized mud blocks made out of soils about 70% sand and 20% fines [silt and clay] is not less than 8% (Venkatarama and Jagadish, 1989; Venkatarama, 1991; Kerali, 2001). Therefore, in this study the stabilizer content was maintained at 10%. The main intention of this study was to use PKSA in combination with cement to evaluate its role in improving the performance of CSEBs. To demonstrate the role of PKSA along with cement, three series of CSEBs, namely S1, S2 and S3 were prepared using different proportions of cement and PKSA as presented in Table 5.

PREPARATION OF COMPRESSED STABILIZED EARTH BLOCKS

The size of the blocks prepared using ASTRAM block

making machine was 305 x 145 x 100mm. The preparation process comprised of batching, mixing, placing the mix, compaction and ejection of the blocks. The density of the blocks was maintained at 2000kg/m³. The required quantities (mass basis) of the ingredients namely, soil, sand, and the stabilizers (PKSA and cement) as obtained from the calculations depending on the series were weighed and initially mixed in a dry condition. Based on initial trials, the optimum water content needed to mould the blocks and eject them successively as one unit was determined by mixing the dry mix of the ingredients with minimum water that is sufficient to obtain a good intact ball without sticking to the hand. For making soil blocks, the proportioned dry mix was spread on big tray, and the calculated quantity of water was sprinkled to the mix and thoroughly worked with hand to have uniform distribution of moisture. Wet mixing was undertaken for further 2–3 min after the addition of water. Then the wet mix was transferred to the mould, placed in position on the ASTRAM machine. The wet mix was remoulded in the mould using a wooden mallet to give proper placement.

The lid of the mould was closed and properly locked at the top. Using the toggle lever mechanism, the mix was pressed to achieve the designed compaction. The soil block was expelled out of the mould by opening the cover. The ejected block was weighed and serially labelled with date of preparation, date of testing and a suitable identification number (for the series adopted) for ease of future identification. All the blocks were compacted in less than 30 min of

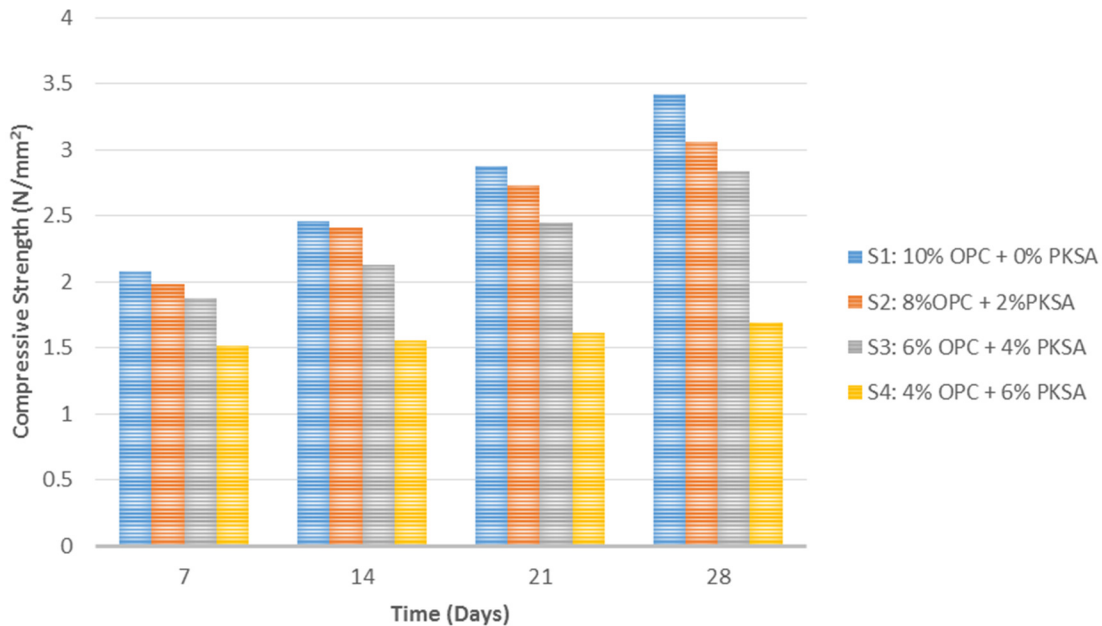


Figure 1. Wet compressive strength test plotted against ageing for CSEBs prepared with different proportions of cement and PKSA.

mixing. The blocks were cured underneath a shade and also kept moist for a period of 28 days. CSEBs were prepared for evaluating their engineering properties, namely, wet compressive strength and water absorption for various ageing periods, namely, 7, 14, 21, 28 days from the date of preparation.

TESTING OF COMPRESSED STABILIZED EARTH BLOCKS

The CSEBs prepared as per the procedure described above were tested for their wet compressive strength and water absorption for different periods of ageing reckoned from the date of preparation as per the prescribed procedures of Bureau of Indian Standards. The test procedures adopted are presented below. The values that resulted in this study are as a result of the average of test carried out on six numbers of blocks at each period of ageing. Wet compressive strength of the CSEBs was determined according to Bureau of Indian standards (IS: 3495-1, 1976). These blocks were later immersed in clean water for 2 days in advance before the date of testing corresponding to ageing selected in the study. Later, the blocks were removed from water, and the surfaces were wiped dry and tested for their compressive strength using Universal

Testing Machine (UTM). The load was applied at the rate of 2 N/mm²/min. PA sheet of plywood approximately 3 mm thick was placed on both sides of the block before the load was applied. Water absorption on CSEBs was done as per Bureau of Indian standards (IS: 1725, 1982). The blocks were oven-dried and their mass was noted. Then the blocks were dipped in water for a period of 48 hours. After this procedure, the blocks were weighed again, and the values for the increased mass was noted in order to calculate for water absorption.

RESULTS AND DISCUSSIONS

COMPRESSIVE STRENGTH

Wet compressive strength [Figure 1](#) presents the plot of wet compressive strength of CSEBs for the four proportions ([Table 4](#)) versus curing periods of 7, 14, 21 and 28 days. An increase in wet compressive strength of blocks as blocks aged was recorded. Further, it can be observed that, the blocks prepared with cement alone (Series S1) have shown to have marginally more wet compressive strength up to 28 days of ageing compared to that of blocks prepared with PKSA and cement (Series S2, S3, S4). The

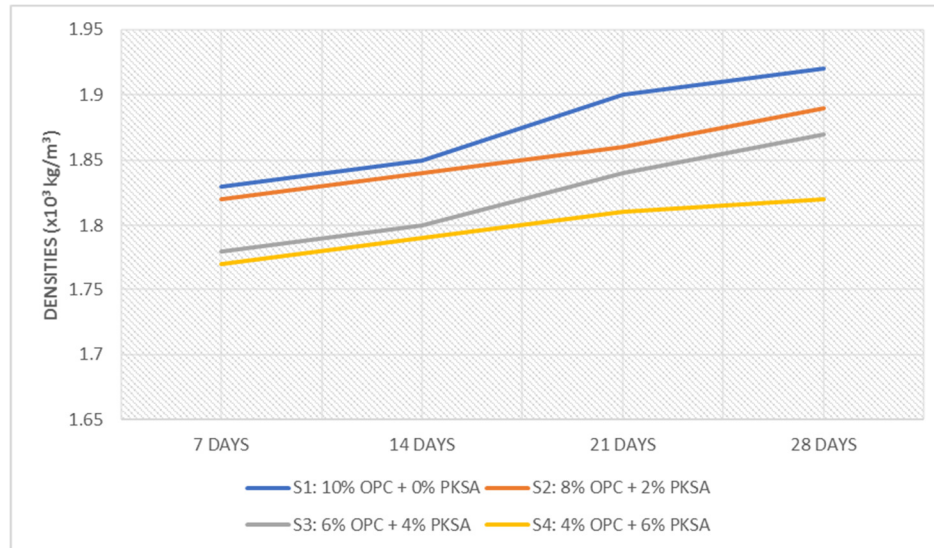


Figure 2. Water absorption plotted against ageing for Compressed Stabilized Earth Blocks prepared with different proportions of OPC and PKSA

relatively more strength of blocks prepared with cement alone at the initial stages of ageing may be due to quick hydration of cement, which helps formation of cementitious compounds in the blocks. For S2 series CSEBs, in which 2% PKSA has been replaced for cement as a stabilizer, it has been observed that strength of these blocks are lower than for the S1 series. This may be due to the reduction of cement in the blocks. Additionally, it has been reported that the slow development of strength is an important characteristic of pozzolans which PKSA is (Olutoge et al., 2012). This may be the probable reason for subsequent block series of to have lower strengths as compared to the blocks S1-series. PKSA has been found to form stable cementitious products due to the pozzolanic reactions and thereby binds the clay particles present in the matrix. In the opinion of some researchers, the strength may increase over many months or even years. Though PKSA-cement concrete has been reported in the literature (Olutoge et al., 2012) its role in imparting long-term build-up of strength in CSEBs has not been reported as presented in this study. The optimum combination of cement and PKSA has been found to be mutually very beneficial in imparting strength to the concrete blocks in a much better way if the right percentage is used, because the cement undergoes self-hydration in presence of water, producing hydration products that bind the sand particles. It is the binding of sand particles, and the products of the

self-hydration of the cement that contribute to the early strength of the blocks. In contrast, the pozzolanic reactions involving clay and PKSA are much slower, rather contributing more to the longer-term strength. Therefore, one can expect gain in strength of the blocks even up to 2 years after their preparation, provided they are prepared with the optimum percentage of PKSA. This would lead to the reduced cost of the blocks and also a better green rating.

WATER ABSORPTION

Water absorption, setting time of the PKSA blocks took longer time than OPC BLOCK, which implies that the presence of PKSA increases the water absorption and setting time of the blocks. Therefore, the higher the PKSA content, the longer the water absorption and setting time. This is so because, the factors that influence setting time are the volume of Portland cement, water requirement and the reactivity of the pozzolan. Despite this, PKSA blocks do not absorb water as fast as OPC blocks; thereby retarding hydration processes in the PKSA blocks (PKSA blocks retain water for a longer period before it starts to dry up slowly).

Figure 2 presents the water absorption of the CSEBs versus ageing for all the three series of blocks used in this study. Over time, there has been a continuous reduction in the rate of water absorption

of blocks. As a result of the cementitious reactions, the interconnectivity between the voids may be getting reduced, and hence, reduction in water absorption of the CSEBs. The values of the water absorption for all the series are much lower than 15%, being around 7–9%.

CONCLUSION

From this experimental study on CSEBs prepared using PKSA as a replacement to cement in certain proportions has clearly brought out the ability of PKSA to be used as a partial cement in earth construction reducing the rate at which cement is consumed. Herein, the combination of cement and PKSA has been found to be beneficial in stabilizing earth blocks (if used in the right proportion) in about the same way when only cement is used. The research findings show a need to look at the strength and water absorption properties beyond 28 days. Further, using stabilizers in combination would help in reducing their quantity in the preparation of blocks of comparable strength to that prepared with cement alone. This would be added benefit not only reducing the cost of the blocks, but also has serious implications in terms of the reduction of energy consumed in the manufacture of blocks when done in large scale. This would also help in a sustainable growth of the society by optimizing the use of agricultural wastes, reduction in energy consumed and lesser pollution of the environment.

When compared with other building materials, CSEB offered a number of benefits. It increases the rate at which local materials are used and also reduces the cost of transportation as the location of the manufacture is on site. This also cause for a reduction in the rate at which construction materials are imported. Generally, this makes good and affordable housing available to more people.

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